Detection and Prediction of Hazards in Ports, Bays and the Littoral Zone: A Lower Chesapeake Bay Test Bed

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LONG-TERM GOALS

The central goal is to integrate scientific resources and understanding so as to enable rapid and effective response to episodic natural or accidental hazards, such as severe storms, harmful algal blooms or toxic spills as well as potential terrorist threats. At the same time, it is intended that by establishing a robust environmental monitoring system in the lower Chesapeake Bay that provides long time series of flows, waves, water levels, water quality and water borne pollutants, pathogens and toxins, we will gain new understandings of complex phenomena while providing operational users with a valuable source of timely information relevant to safety and environmental stewardship. For addressing specific Navy needs, we also aim to provide the Navy with a portable suite of sensors, models and informatics techniques for detection, diagnosis, and predictions of manmade and natural water-borne hazards and threats, including intrusions, water-borne pollutants, pathogens and toxins in ports, bays and littoral waters.

OBJECTIVES

Specific scientific and technological objectives of this program fall into two closely integrated categories: Element 1 *Marine Biohazards and Toxins* and Element 2 *Implementation of an Integrated Observation and Modeling System.*

Specific objectives of Element 1 include:

- Refining methods for identifying pollutants and bioactive compounds.
- Using new tools to detect pollutants and bioactive compounds in our coastal oceans.

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- Monitoring targeted compounds in Virginia's ports and harbors.

Some specific objectives of Element 2 include:

- Assimilating data from existing sources as well as from new moorings into models.
- Providing hourly physical and biogeochemical information from moorings.
- Providing computer model predictions of the occurrence and pathways of hazards.
- Developing new, rapidly deployable observing methodologies.
- Generating web-accessible maps of coastal water movements and inundation levels.
- Improving predictive models of inundation in fetch-limited bays and harbors.

APPROACH

Methodologies for Element 1: Marine Biohazards and Environmental Toxins Research

Specific antibody probes to polycyclic hydrocarbons (PAH) are being developed to permit the detection of oil spills and give a relative measure of the time post release. Oils with some of the highest aromatic contents include Fuel Oil #2, kerosene, and diesel, the type of oil most likely to enter the aquatic environment from all forms of ship traffic. Combined with real time physical measurements and transport models, a suite of contaminant detector systems could permit early oil spill detection and identification, assessment of oil slick weathering and transport. Antibody probes are being screened for their suitability for use within real-time sensors based on either optic fiber or fluid phase fluorescent detection technologies. VIMS is currently evaluating the capabilities and costs of these technologies with industry collaborators and will proceed with the most practical and sensitive technologies. Key personnel involved in this facet are S. Kaattari, M. Unger, E. Bromage (post-doctoral associate) and C. Spier (graduate student).

Methodologies for Element 2. Integrated Observations and Modeling

a. In-Situ Sensing Methods

The prototype mooring supports the multiple instruments indicated in Figure 1. Over the course of the next year, it is intended to replicate this system for real time observations of waves and currents at a total of four locations and thus to provide the necessary complement to existing data sets within the lower bay region. For physical measurements, bottom-mounted pods typically support pressure, conductivity and temperature sensors and an upward-aimed acoustic Doppler current profiler (ADCP) to measure currents throughout the water column as well as directional wave spectra. Other sensors provide information on vertical density stratification, suspended matter, winds, biomass, and water quality. The surface buoys support meteorological and in situ water quality sensors, perform initial data processing, store raw and preprocessed data and regularly communicate the data to shore. The data are collected hourly on a land-based server, subjected to initial rapid QA/QC screening, and stored in forms ready for dissemination via the CBOS website. Surface buoys attached to observational platforms transmit information to shore stations. Personnel include C. Friedrichs, J. Brubaker, L.D. Wright, T. Nelson (electronics technician) , J. Vandever (graduate student) and L. Brasseur (Graduate student).

b. Coupled Numerical Models

Modeling is aimed at providing highly resolved (in both space and time) “nowcasts” and short-term forecasts. Community models that are accessible to the research community as a whole (usually open-source), and have some level of acceptance, support, and history of use throughout the community are favored in this study. During the first phase of this program, observational data is being assimilated into a highly resolved unstructured three-dimensional model to serve as a test bed for making real-time forecasts of water elevation and velocities within the lower Chesapeake Bay. Figure 2 shows the model grid and lists models in use. The program provides common data sets for comparing different models’ abilities to perform in estuarine settings. Numerical modeling personnel are H. Wang and J. Shen.

c. Data Management and Communication (DMAC)

Development of the observing system is consistent with the perspective of the national IOOS program, where the role of DMAC is given prominent and extensive attention. Data are made available through the OPeNDAP (Open-source Project for a Network Data Access Protocol) system evolved the older system known as DODS (Distributed Oceanographic Data System). Various data streams supply information to the server along with image files from cameras. Raw ADCP and water quality data are converted to netCDF files. Direct local access is provided to the data for the numerical models and data analysis programs. Key personnel are J. Brubaker, L. Brasseur and T. Nelson.

WORK COMPLETED

Since funding for this program only became available in April of 2005, the program is still in the early stages of implementation. Nevertheless, advances have been made on several fronts.

1. Marine Biohazards and Environmental Toxins Research: Four hydrocarbons indicative of an oil spill have been identified for probe development, they; they are alkylated derivatives of benzene, phenanthrene, naphthalene, and biphenyl Techniques for the conjugation of these PAH's to protein carriers required for immunization and detection have been optimized. Polyclonal antisera generated following immunization has been demonstrated to be specific to the parent compound and has allowed PAH detection in standard laboratory tests (ELISA) down to parts per billion. An experimental real time sensor prototype has been successful in detecting both our lab standard antigen / antibody as well as PAH's in solution, and further testing is ongoing. Five fusions (processes for production of the antibody probes) have now been executed and testing of these probes is underway. We are also providing these probes to our industry partners for adapting these probes to their sensor technology.

2. Observing system deployment: VIMS has already begun implementation and interfacing of aspects of an observing system that will validate accurate and timely model predictions. Two buoys similar to that illustrated in Figure 1 have been built and one has been deployed. Figure 3 shows a deployment taking place in July. The system provides simultaneous measurements of winds, waves, and currents at different levels of the water column, water density, nutrients, water quality, and biological indices under all conditions.

3. Modeling: High spatial resolution, three-dimensional numerical models of the York River and of the Chesapeake Bay and adjacent shelf have been implemented using the computationally efficient UnTRIM model. A tidal (water level) calibration was completed, with good agreement between the

model and NOAA tide predictions. Results at each model cell (121,338 locations in the Bay/shelf model and 55,772 in the York River model) include water level as well as velocity at a series of depths.

4. Data Management and Communication (DMAC): An OPeNDAP/DODS server has been implemented and several modes of access have been demonstrated. A directory structure has been established and populated with sample files for various kinds of observing system data. Matlab code to convert raw data files from instruments into netCDF files for the OPeNDAP server was developed. Data can be accessed by: *(1)* Direct URL entry into web browser; *(2)* Navigating the website www.vims.edu/realtime/ ; or (*3)Utilizing* The OPeNDAP Data Connector tool. Data access is not limited to OPeNDAP.

RESULTS

Figure 4 shows the specificity of an antibody probe generated against an alkylated biphenyl. The only PAH that could inhibit the antibody activity was the parent compound (4'-methyl-biphenylcarboxylic acid) demonstrating a high degree of specificity. The antibody probe was able to detect the target PAH at concentrations as low as 0.001 microgram per mL or 1 part per billion.

The VIMS observing system is in an early phase of development. The central result at this stage is the implementation of a complete observing system infrastructure consisting of subsystems for: data acquisition, data management and communication, and numerical modeling. All major elements of the system have been demonstrated in operation. The infrastructure provides the deployment platforms, operating power, data transmission, data management, and fine-grid modeling capability for a variety of applications and sampling programs.

IMPACT/APPLICATIONS

From an operational perspective, the major applied emphasis of this initiative will be on Predicting Hazards and Supporting Safe Operations in Coastal and Estuarine Waters. This theme is highly pertinent throughout the Gulf Coast and Eastern Seaboard. Initial emphasis will be on Chesapeake Bay, but once the prototype development is complete, attention will turn to pre-operational approaches for use in all bays, ports and harbors of the world. The capabilities developed through this program will serve numerous user groups including: Coast Guard (search and rescue and oil spill tracking); ocean scientists; maritime interests; Navy; emergency managers; commercial and recreational fishers; beach-goers; pleasure boaters; and regional planners. Data and model outputs from this system will be open to access by the research community in near real time.

TRANSITIONS

Web access of data and model output maps contributes to education and outreach activities. This program has intersected from the outset with COSEE programs in the Middle Atlantic Region and elsewhere. Web-accessible visualization of real-time data and model output contributes to public understanding of coastal and estuarine processes. Links to the output are made through "The Bridge" a VIMS-based web resource for high school teachers.

RELATED PROJECTS

Detection of Water-Borne Hazards in Bays, Ports and Estuaries: A Program to Enhance Safety in the Lower Chesapeake Bay, Commonwealth of Virginia, July 2004 to June 2005.

Chesapeake Bay Observing Cooperative Expansion and Integration Demonstration. National Oceanic and Atmospheric Administration, October 2004 to September 2005.

A Real-Time and Rapid Response Observing System for the Study of Physical and Biological Controls on Muddy Seabed Deposition, Reworking and Resuspension. National Science Foundation, January 2006 to December 2008.

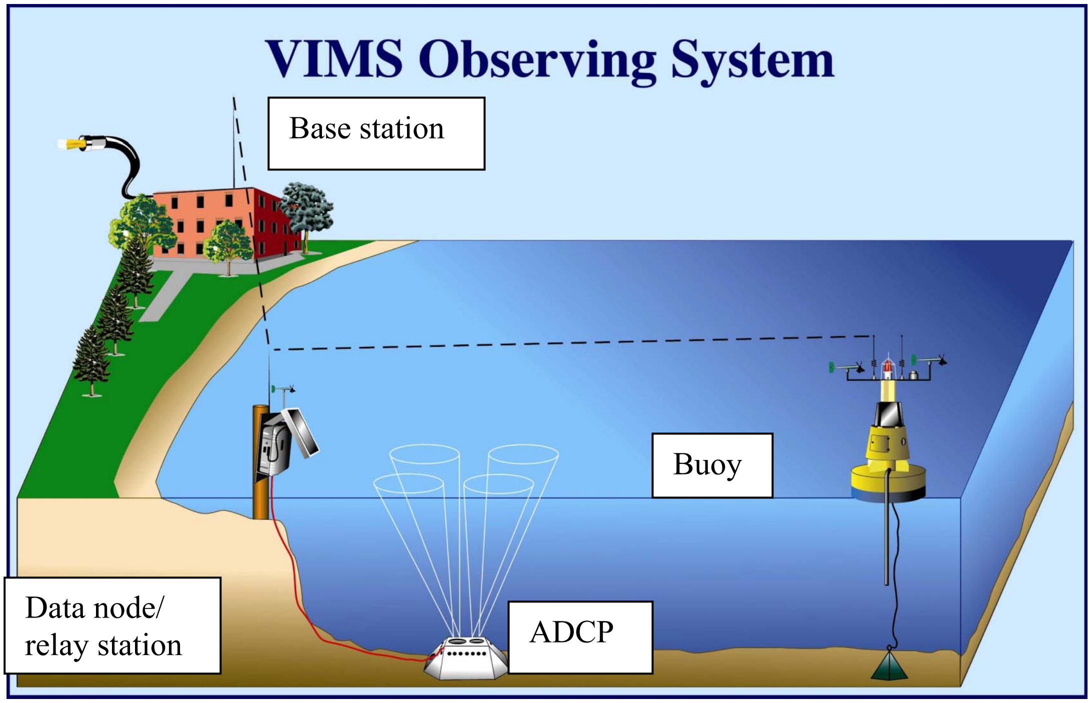
PUBLICATIONS

Brasseur, L.H., J.M. Brubaker, and C.T. Friedrichs, 2005. Vertical mixing processes in the York River estuary from observations and modeling efforts. Submitted to the 18th Biennial Conference of the Estuarine Research Federation, Norfolk, VA, 16-20 October.

Brubaker, J., L. Brasseur, C. Friedrichs, T. Nelson and L.D. Wright, 2005. ADCP-based determination of directional wave spectra in the York River estuary. Quality Assurance of Real-Time Ocean Data Workshop, Norfolk, VA, 2-4 March.

Friedrichs, C.T., J.M. Brubaker, L.D. Wright, W.G. Reay, T. Nelson, and L.H. Brasseur, 2005. The Virginia Institute of Marine Science Estuarine Observing System. Submitted to the 18th Biennial Conference of the Estuarine Research Federation, Norfolk, VA, 16-20 October.

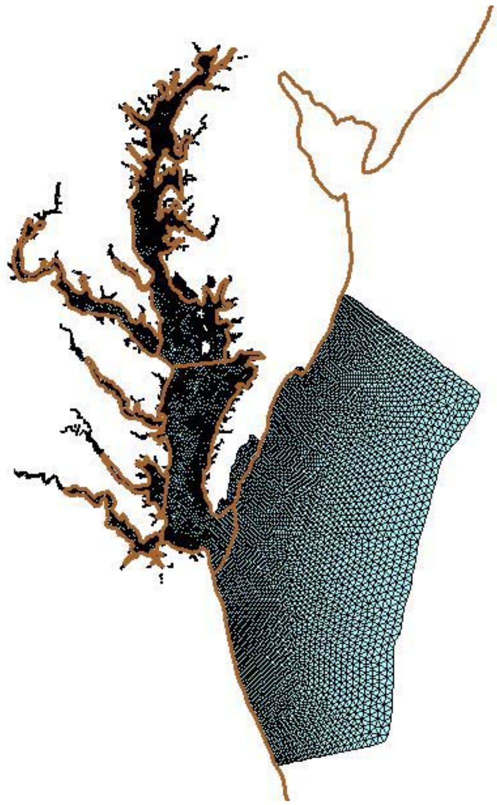
Vandever, J.P., J.M. Brubaker, and C.T. Friedrichs, 2005. ADCP measurement of waves in the York River estuary, Virginia, USA. Submitted to the 18th Biennial Conference of the Estuarine Research Federation, Norfolk, VA, 16-20 October.



Mooring Instrumentation

Instrument/sensor	Measurement	Variable
Acoustic Doppler Current Profiler (ADCP)	Current speed and direction; turbulence; waves; acoustic backscatter	Directional Wave Spectra; current vectors; suspended sediment concentration
CT module	Conductivity, temperature	Salinity, density, temperature
Fluorometer	Chlorophyll *a* fluorescence	Phytoplankton biomass
Optical backscatter sensors	Turbidity	Suspended particle load
		.
Dissolved oxygen sensor	Dissolved oxygen concentration	Oxygen (mg l)
Meteorological module (ESM-1)	Winds, temperature, and pressure	Meteorological parameters just above sea surface
Pressure sensors	Pressure fluctuations at bed	Waves, tides, storm surge
Video camera	Visual images of sea surface	Surface conditions

Figure 1. Schematic representation of the primary components of the data acquisition subsystem of VIMS-CBOS.



Coastal Numerical Models in Use at VIMS

Application	Model Name (Acronym)	Supporting Institution
Circulation	CH3D-Chesapeake Bay	VIMS/WES
Circulation	Princeton Ocean Model*	Princeton University
Circulation	ECOM-SED*	Hydroqual
Circulation	Coastal Ocean Forecast Sys.	NOAA
Circulation	UnTrim (not open source)	Univ. Trenton/VIMS/USGS.
Circulation	EFDC	Tetra Tech/VIMS/EPA
Circulation	Navy Coastal Ocean Model (NCOM)	Naval Research Lab
Wave	REF/DIF*	VIMS/Univ. Delaware
Wave	SWAN*	Univ. Delft/LSU/VIMS
Storm surge	SLOSH*	NOAA/VIMS
Storm surge	EFDC	Tetra-tech /VIMS
Water Quality	HEM3D*	VIMS

* Open source community models

Figure 2. Spatial grid for the UnTRIM numerical model of the Chesapeake Bay and adjacent continental shelf and summary of models in use.

Figure 3. Data buoy and bottom mounted acoustic Doppler current profiler being deployed in the lower York River estuary, July, 2005.

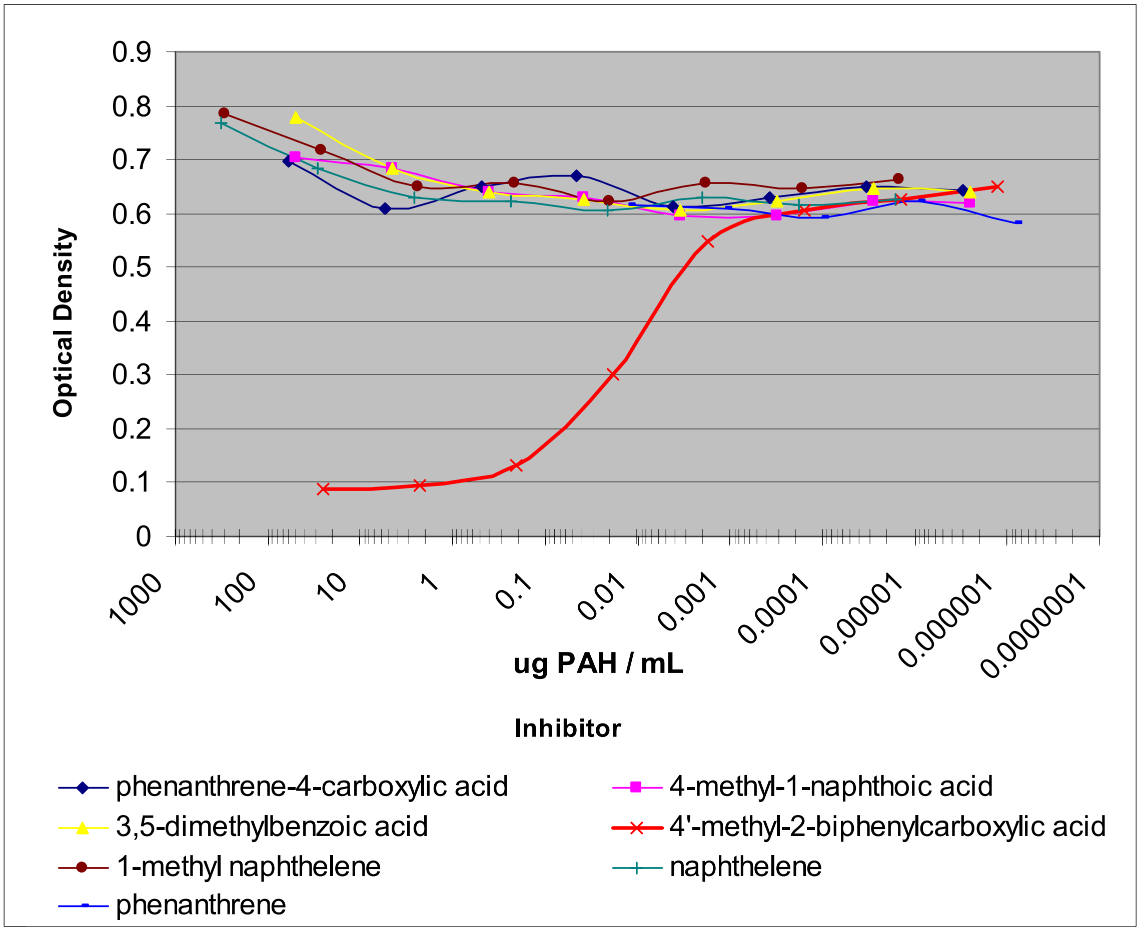


Figure 4. The specificity of the antibody probe generated against 4'-methyl-biphenylcarboxylic acid. Only the target PAH (4'-methyl-biphenylcarboxylic acid; red curve) binds the antibody, thereby producing a signal (reduced Optical Density). No other PAHs bind the antibody probe, thus the probe is highly specific.